ANACONDA Minerals Company Internal Correspondence

3.2.3

Date: September 11, 1984

Subject: Coke Calcining

coking costs 278

From/Location: D. Malmquist

To/Location: R. Loutfy

Costs for producing steam-activated carbon from green petroleum coke have been estimated based on the requirement of 78,000 tons per year of carbon. This study was summarized earlier in a memo from D. E. Malmquist to R. Loutfy, "Coke Calcining" dated May 10, 1984.

The current memo is a more detailed report of the estimate, including assumptions, references, and methodology. A few minor changes have been made since the May memo, resulting in insignificant changes in some of the calcined coke costs.

The calcining cost information provided by Arco Petroleum Products should be treated as confidential.

David E. Malmquist

D. E. Malmquist

DEM/dc

cc: R. W. Bartlett
E. L. Cambridge
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BACKGROUND

As the link between the ARCO Chloride Process and the Alcoa Chloride smelter alumina is reacted with chlorine gas and carbon to produce aluminum chloride:

(1) $$Al_2O_{3(s)} + 3/2C(s) + 3Cl_{2(g)} \rightarrow 2ALCl_3(g) + 3/2\ CO_2(g)$$

The Al_2O_3 in the feed is produced by the Arco Process, and the $AlCl_3$ in the product is the feed to the Alcoa process.

Since C° is consumed in the reaction, it is critical to the process economics that the cost of the C° be as low as possible. However, the C° must also be relatively pure to prevent contamination of the $AlCl_3$. Stoichiometrically, 0.33 lb C° is required per lb Al°, but taking inefficiencies into consideration, the anticipated requirement is 0.4 lb C° per 1.0 lb Al°.

In addition to being pure and inexpensive, the carbon used must also be reactive and uniformly sized. The size requirement is because the chlorination reaction is done in a fluidized bed, and to be efficient, the fluidization characteristics must match those of the alumina. The reactivity requirement is for reaction kinetics.

An obvious source of carbon is commercial, activated carbon, such as Witco 950. However at roughly $1000 per ton, the cost would be 20¢ per pound of aluminum, which is obviously out of the question. According to the literature, activated carbon is frequently produced by steam-calcining carbonaceous material such as coal, coke, shells, fruit stones, etc. Equipment used includes rotary kilns,shaft ovens, rotary hearth and fluid bed reactors.

The most common source of carbon for the aluminum industry is from petroleum coke. However, this product is fully calcined green petroleum coke and is essentially non-reactive. Petroleum coke is calcined in either a rotary kiln or a rotary hearth furnace.

The product required for the Arco Chloride Process is neither activated carbon nor fully calcined coke, but rather somewhat of a cross between the two. It must be more reactive than fully-calcined coke, but does not have to be as fully reactive as activated carbon. A suitable product has been produced in the lab by steam-calcining green coke at 950°C in a fluidized bed reactor.

EQUIPMENT

Most petroleum coke is calcined in either horizontal rotary kilns or in rotary hearth calciners. The rotary kiln has been the standard coke calciner for years, and although the rotary hearth is gaining popularity, there are still many new rotary kilns being installed.

A typical rotary kiln coke calcining plant is shown as Figure 1.[1] Kennedy Van Saun, a major manufacturer of rotary cilns for coke calcining, in their brochure on coke calcining[2], describes calcining and rotary kilns as follows:

> During the calcining process, the moisture and volatiles are removed from the coke. Simultaneously, the coke passes through an expansion and a contraction phase before it reaches its final density.... Because the real density desired, is achieved by the degree and the intensity of heat treatment subsequent to devolatilization, it becomes a measure of this heat treatment...
>
> The calcination may be considered as taking place in stages as the green coke advances down the kiln. The moisture is driven off in the first section of the kiln followed by heating of the coke to devolatilization temperatures. Complete calcining of the coke takes place in the firing zone... The temperatures in the kiln range from 1400°F - 2400°F (760°C-1090°C) at the feed end... to 2400°F-2700°F (1315°C-1480°C) at the firing end...
>
> The calcined coke is discharged from the rotary kiln into a rotary cooler... The volatiles, which are driven off, are partially burned in the kiln proper before passing into a dust plenum chamber and from there into an afterburner.
>
> In the afterburner the remainder of the volatiles, as well as the carbon monoxide and coke particles carried out as dust, are burned off.

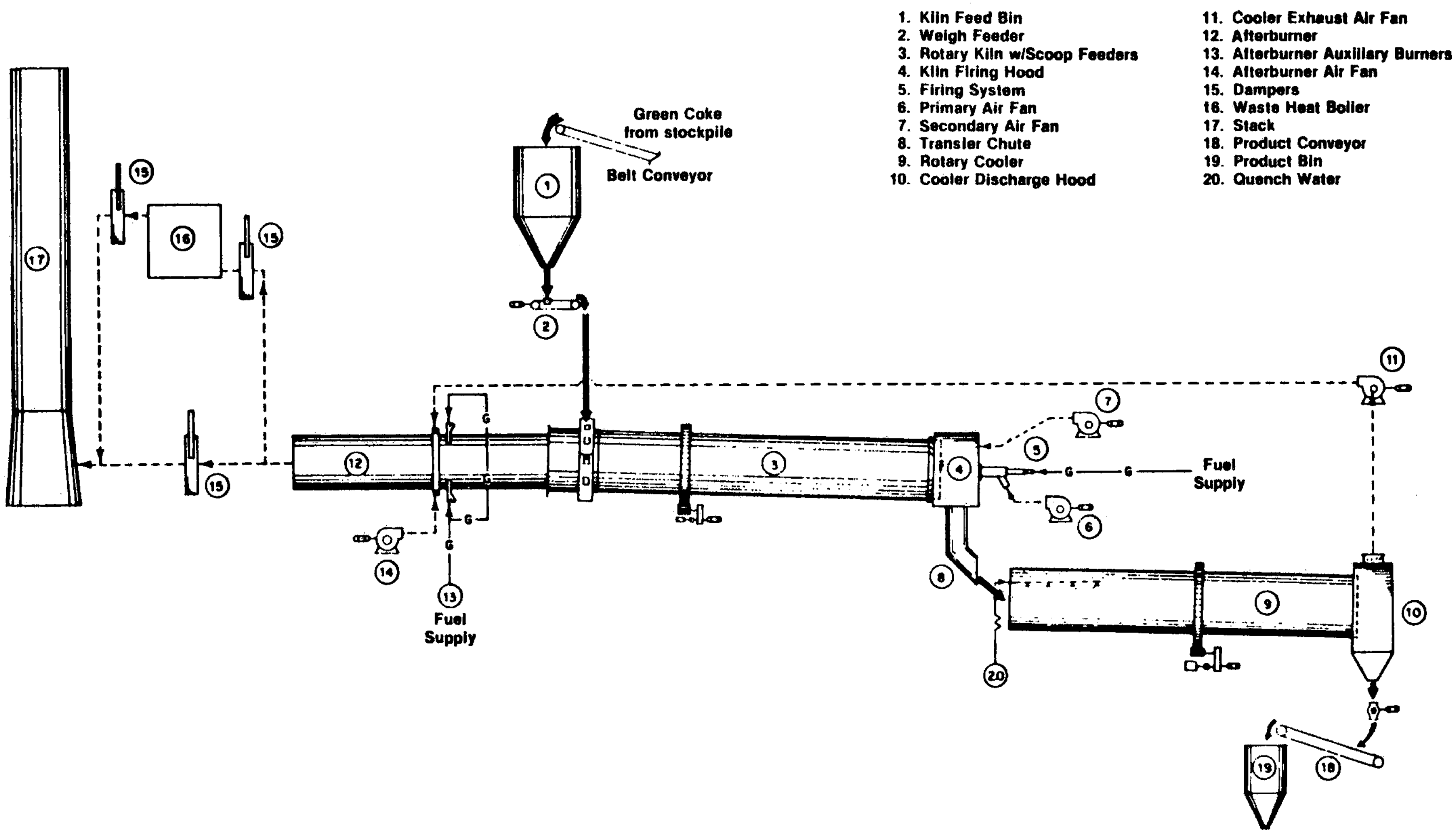

FIGURE 1 – TYPICAL ROTARY KILN CALCINER

> The afterburner exit gases carry a considerable amount of heat with them...which can be utilized in a waste heat boiler, for example to generate steam...

Rotary kilns for coke calcining are typically 10-14 ft in diameter and 180-300 ft long. Capacities range from 100,000-300,000 STPY calcined coke.

A typical rotary hearth calciner is shown in Figure 2[3], with a section of the hearth shown in Figure 3[4]. Rotary hearth petroleum coke calciners were first developed as a joint venture between Marathon Oil and Wise Coal and Coke Company. The first Marathon-Wise calciner was put into service in 1967[5].

In the rotary hearth calcining operation, green coke is fed by gravity through a feed chute to the outer edge of the calciner. Coke is then "plowed" toward the center of the hearth in a spiral pattern by a series of rabbles. Retention time is dictated by rotation speed, and one hour is a typical, nominal time. At the center of the calciner is a soaking pit which retains the coke for several more minutes and assures temperature uniformity, acts as a surge bin, and provides a seal between calciner and cooler. Calcined coke is cooled in a rotary cooler.

Manufacturers of both types of calciner point out the advantages of their equipment, and it is obvious that each has its virtues. The rotary kiln is less costly to install than the rotary hearth, and that fact probably accounts for many of the recent installations. The rotary kiln is simple, has a high throughput rate, and has been used for many years; most coke calcine operators are familiar with it. The most commonly quoted disadvantage of the rotary kiln is the fact that it is not efficient enough to be thermally self-sufficient for fully calcining coke. Even after startup, a continual operation of a burner on the discharge end is required to achieve total calcining. The disadvantages of this are the added fuel costs and the loss of fines entrained in, and carried out with, the combustion air. A further disadvantage of the rotary kiln is that it is more difficult to seal from infiltration, making control of the calcining environment more difficult.

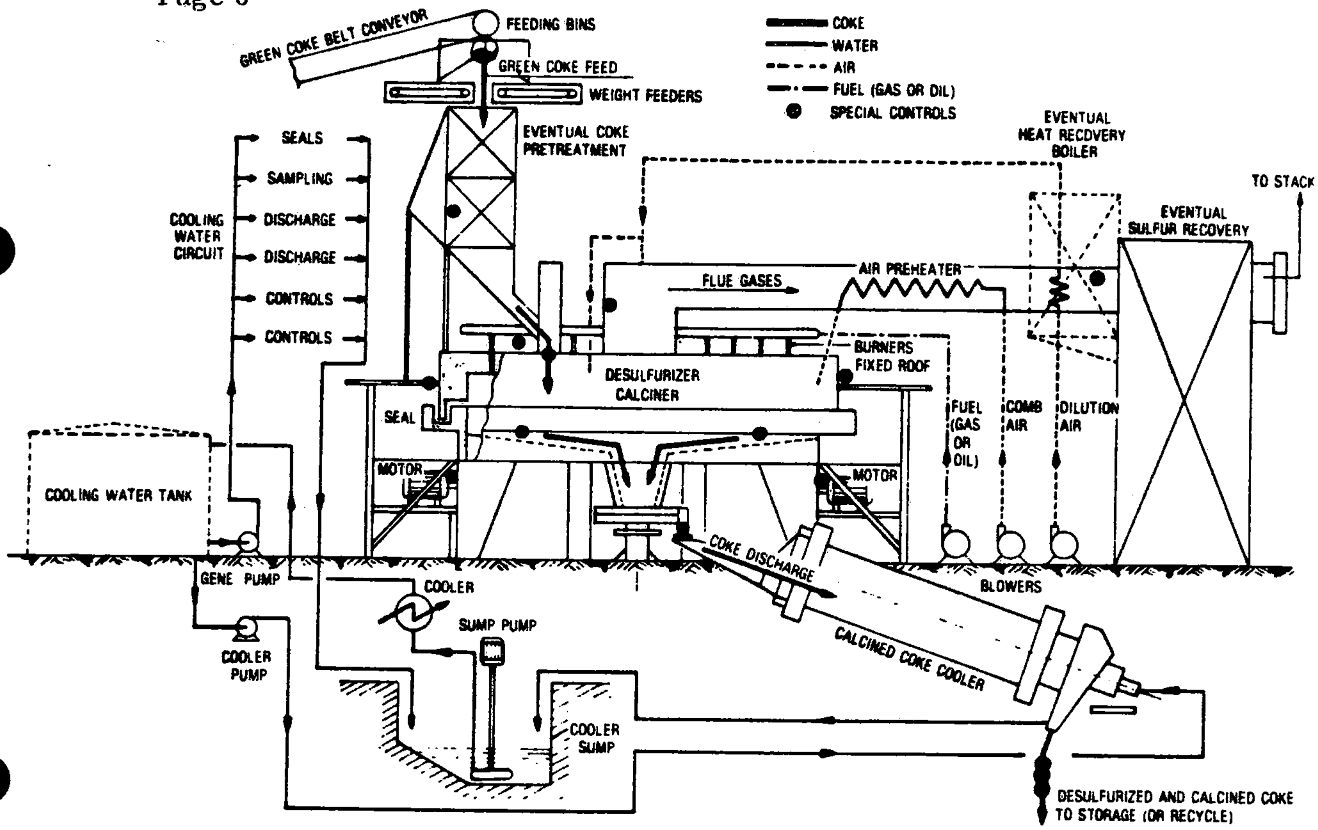

FIGURE 2 – TYPICAL ROTARY HEARTH CALCINER

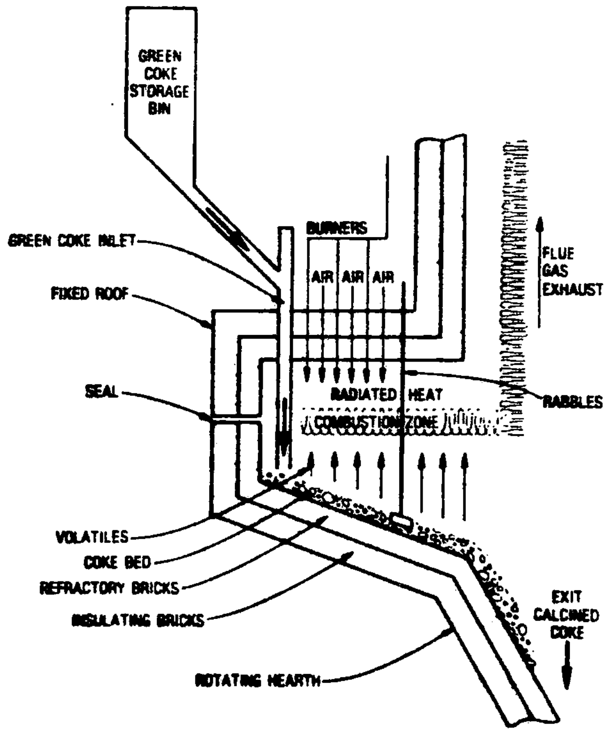

FIGURE 3 – SECTION OF ROTARY HEARTH CALCINER

The most commonly-stated advantages of the rotary hearth are the low fuel requirements and the higher carbon recovery. Once the calciner is up to temperature, the combustion of volatiles in the rotary hearth provides more than enough heat to sustain the calcining operation. Because the environment in the rotary hearth is more accurately controlled, and because waste gases exit at relatively low velocity, less carbon is burned in the calcining process, and less carbon is mechanically carried out in the off-gas stream. Mechanical losses of fines is also minimized by the fact that finer particles tend to work down into the bed. Refractory wear is very low, since a dead bed of coke below the active area protects the refractory from abrasion. The biggest disadvantage of the rotary hearth is the initial capital cost, which is about 25% higher than for a rotary kiln.

Vendors of both rotary hearths and rotary kilns were contacted concerning the use of their equipment for steam calcining petroleum coke. Salem Furnace Company, licensors of the Marathon-Wise process was questioned about rotary hearth applications, and Kennedy Van Saun Corporation, a major rotary kiln manufacturer, was contacted about kilns. Also, several Atlantic Richfield employees from both Harvey Technical Center and Cherry Point Refinery were consulted. No one had any experience with steam calcining petroleum coke. However, it is reported that Witco has produced some activated carbon by steam/CO_2 activation of acid sludge in a rotary hearth calciner[6].

Since there is apparently no precedence for steam-calcining petroleum coke, some assumptions had to be made. Those assumptions are:

(1) Petroleum coke can be steam-calcined in any of the same basic equipment that is used to fully calcine coke. Both Salem Furnace and Kennedy Van Saun indicated that this assumption is probably valid, although neither would commit themselves since they did not have direct experience.

(2) Modifications to existing calcining equipment to permit the use of steam would cost only a nominal additional capital. This assumption seems reasonable, since steam is already being generated from waste heat from the calciner, so all that is required is to put part of it back to the calciner. Some allowance would also have to be made for additional flue gas volume, but this should also be minimal. An added verification of this assumption is that in the total cost of a calcining facility, perhaps only 25% would be associated with the equipment that would contact steam. The remainder, green coke handling, coolers, product storage, etc., have nothing to do with steam being used. Even if the steam-related equipment were doubled in cost, which is highly unlikely, the total calcining cost would only go up by about 25%. One area of concern on equipment, however, is green coke feed size. Normal calcining operations use coke at 3-4 inch feed size to minimize dust losses. The steam calcining is based on much finer feed and may result in high dust losses.

(3) Operating cost is the same for calcining with or without steam. This assumption is based on the fact that calcining generates "free" steam that is not needed elsewhere in the plant. It ignores the fact that excess steam has the potential to generate electric power if available in enough quantity.

COKE REQUIREMENTS

The final calcined coke requirement that must be satisfied is 0.4 lb coke per lb of aluminum, sized at -65 mesh +150 mesh. For a 195,000 ton per year aluminum smelter, the requirement is 78,000 tons per year coke. Assuming 95% operating time, the design rate is 82,105 tons per year. It was further assumed that dry green coke would lose 30% weight during calcining -- 14.2% by pyrolysis and 15.8% by volatile loss.

With regard to sizing, little information is available concerning the degradation during calcining, fines produced during grinding, or size requirements in steam calcining necessary for effective activation. For the purposes of this evaluation, it was assumed that calcining would be done on -28 mesh +65 mesh coke. Feed size for Santa Maria fine coke was provided by Union Collier and is shown in Table 1.

TABLE 1

FEED SIZE FOR SANTA MARIA FINE COKE

Size Analysis	% Distribution
+6	21%
-6 + 10	24
-10 + 20	16
-20 + 35	15
-35 + 60	8
-60 + 100	6
-100	10
	100%

Figure 4 shows the assumed materials balance that was used for sizing equipment. Each screening/milling step uses a total of 20% loss to fines (combined original fines and grinding-produced fines). Adding both sizing losses and calcining losses, the result is that for every pound of useable calcined coke produced, you must start with 2.22 pounds of dry green coke.

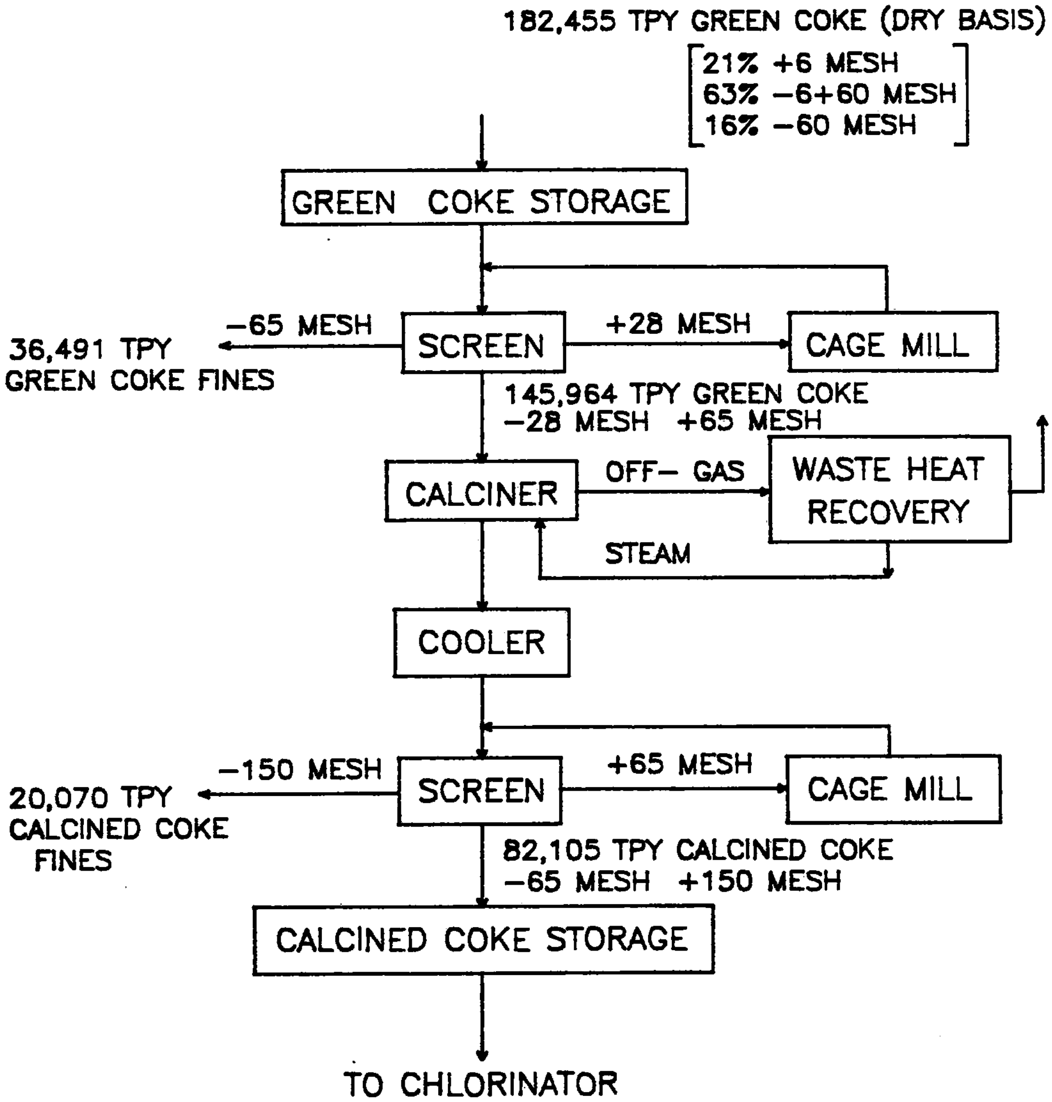

FIGURE 4 – STEAM CALCINING BLOCK FLOW DIAGRAM

CAPITAL COSTS

For purposes of obtaining capital costs for calcining, a rotary hearth installation was chosen. The reasons for using the rotary hearth as the basis were:

(1) Reportedly used by Witco for activated carbon

(2) Less loss of fines during calcining

(3) Most recent and complete information available for rotary hearth.

Of these reasons, the final one was by far the most significant. Arco installed a rotary hearth petroleum coke calciner in 1978-79 at the Cherry Point, Washington refinery, and cost information is available on that installation. Adjustments were made to the Cherry Point costs based on capacity, feed and product storage requirements, and site or product-specific items. Costs were then escalated to 1984 dollars.

Table 2 shows the estimated capital cost for steam calcining, derived from adjusting Cherry Point costs. Details of the adjustment are shown as Appendix I. It should be noted that even though Cherry Point costs were used as a basis, and information was provided by various individuals from Arco Petroleum Products, the estimate is a product of Tucson and has not in any way been endorsed by Cherry Point or Harvey Technical Center. The total capital cost, including a 25% contingency, as shown in Table 2 is estimated to be $34.6 million. This estimate should be considered conceptual.

TABLE 2

ESTIMATED CAPITAL FOR COKE CALCINING

Item		Total Installed Cost ($M)	
Columns & Vessels		$	15
Tanks			1,564
Heat Exchangers			1,026
Rotary Hearth			4,208
Waste Heat Boiler			1,399
Pumps/Drivers			81
Special Equipment			2,766
Buildings			3,000
Site Development			1,000
	Total Directs	$	15,059
Field Indirects			2,881
	Total Field	$	17,940
Engineering & H.O.			2,047
Fee			461
	Sub-Total Capital	$	20,448
Spares			133
	Total	$	20,581
Contingency (25%)			5,145
	TOTAL CAPITAL Cost (1979 $)	$	25,726
	(1984 $) =	$	34,631

OPERATING COSTS

The major operating cost for the calcining is the cost of the green coke. This cost would ultimately have to be negotiated with a petroleum refiner, but for the purposes of this estimate Santa Maria coke was valued at $25.00 per ton, f.o.b. California. Cost for shipping from California to the Gulf coast by unit train is estimated at $25.00 per wet ton. At 10% moisture, the total delivered cost of green coke is $52.78/ton. Allowing for 30% losses during calcination and assuming that the green and calcined fines have a sales or use value equal to their cost, the final green coke cost is $75.40 per ton of calcined coke.

The other operating cost to consider is the actual cost of running the calcining operation. The major components of this cost are electric power, labor, and maintenance. Operating costs for rotary hearth calciners have been reported to be in the range of $6.50-$10.00 per ton of calcined coke. Since labor, power, and maintenance are essentially the same whether steam is used or not, it should be reasonable to assume the same operating costs for steam calcining as for standard calcining. To allow for possibly higher maintenance costs because of the steam, the upper end of the range was used — $10.00 per ton of calcined coke.

TOTAL COST

Based on the preceeding discussions of capital and operating cost, the total cost of calcined coke is estimated to be $145.34 per ton. This is a summation of direct operating cost ($10.00/ton), coke cost ($75.40/ton), and annual capital charges ($59.94/ton).

The capital charges are arrived at by using 13.5% of total capital per year. This is approximately the annual cash flow over 20 years that would be required to yield an investment efficiency of 0.4 on the capital cost.

ALTERNATE CASES

Several alternate cases were costed in order to try to more reasonably bracket the cost of calcining. These cases are described below; and summarized in Table 3.

(1) Low Case - In this case, the cost of delivered green coke was unchanged, but capital and operating cost were both reduced. Capital was reduced by reducing the product storage from 21 days to 10 days, by reducing the green coke storage from 2 months to 1 month, and by reducing the contingency from 25% to 10%. This brought total capital down to $26.3 MM, or $45.57/ton of calcined coke. Also for this case, operating cost was taken at $6.50/ton which is at the low end of the range rather than the high end.

(2) High Case - For the high case, it was assumed that the capital was twice the base case for the rotary hearth calciner and the dust collection system. These areas are the ones which may be affected by changing the size of the feed material and adding steam. These changes brought total capital up to $44.577 MM, or the equivalent of $77.15 per ton of coke. In addition to capital, operating costs were increased by 25% over the base case to $12.50 per ton of coke. As in the low case, the cost of green coke was held constant at $75.40 per ton of calcined coke.

(3) Extreme Case - In addition to using the capital and operating cost from the high case, the extreme case also assumes higher green coke costs. In the base case, it was assumed that the under-sized coke

TABLE 3

COKE COST PER TON OF CALCINED COKE

	Capital*	OPC	Green Coke	Total
Base Case	$59.94	$10.00	$75.40	$145.34
Low Case	$45.57	$ 6.50	$75.40	$127.47
High Case	$77.15	$12.50	$75.40	$165.05
Extreme Case	$77.15	$12.50	$117.29	$206.94
Rotary Kiln Case	$47.95	$12.50	$82.25	$142.70

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* Based on a capital recovery factor of 13.5% per year, and on 78,000 TPY coke production.

(green or calcined) could be sold or used at cost. The extreme case assumes that the undersized coke has no value whatsoever, and is a disposal product. This increases the cost from $75.39 to $117.29 per ton of calcined coke. (No costs have been added for the actual disposal of the coke, since it is assumed that although the product has no value, it could be given away.)

(4) Rotary Kiln Case - Although a rotary kiln was not costed in any detail, a rough estimate was made using data from Table 4[7]. Capital costs were decreased from the base case by 25% from the base, rotary hearth case to $27.7 MM. Operating cost was increased by 25% to $12.50/ton. Yield was reduced by about 10%, which caused the cost of green coke to increase to $82.25 per ton of calcined coke.

DISCUSSION

As seen in Table 3, the most expensive component in coke calcining is the cost of the green coke. In all but the low case, the green coke accounts for more than half the total calcined coke cost.

The green coke cost has two components — actual cost and transportation cost. Because of losses during screening and calcining, only 45 tons of calcined coke is recovered from every 100 tons purchased and shipped. If calcining could be done at the refinery where the green coke is produced, only calcined coke would be shipped, resulting in a freight savings of over $10 per ton of calcined coke. An additional advantage of calcining at the refinery may be that the off-sized products may be more useful there than at an aluminum smelter, although the opposite may also be true.

Capital and operating costs, while arrived at in a fairly crude fashion, are felt to be relatively accurate, given that the basic assumptions are correct. Operating costs should not be significantly different from a normal calcining operation, and the range used for operating costs is a valid one obtained from actual operations.

TABLE 4

COMPARISON OF CALCINING PROCESSES

Items	Rotary Kiln	Rotary Hearth
Investments Relative %		
Major equipment	100	125
License	100	200
Engineering Proc.	100	120
Engineering Civil	100	80
Utility Consumption		
Heat, MM Btu/ton*	1.1	1.5
Water, Cooling cu m/ton	0.7	1.0
Elec. kwh/ton	38	42
Maintenance		
Downtime, days/yr	30	15
Spares, % of equip.	15	12
Labor, kiln, men/shift	2	1
Product Quality		
Yield, % Expected	88	96
Density, g/cc (max)	2.08	2.16
Uniformity, g/cc (max)	0.03	0.002
Sulfur, wt % in coke (max)	1.2	1.2
Sulfur, wt % in feed (max)	1.4	1.5
Payout		
Time, years	4-5	3-4

* Maximum heat for startup only.

Capital costs may vary depending on the particular calcining equipment used, but as discussed earlier, much of the capital is constant regardless of which calciner is used, so the margin for error is diminished. (In this regard, a fluid bed calciner was discussed but not costed. One would probably not be too much in error to assume that the cost of a fluid bed calciner would not differ greatly from the cost of a rotary hearth or a rotary kiln, although the equipment <u>is</u> different enough that this assumption is probably on a much weaker base than the others used).

The requirement of the coke to be uniform and relatively small-sized introduces several problems to the evaluation. In addition to the problem of having to find a use for the fines produced (or already present in green coke), the calcining of finer material may cause operational problems.

Figure 5 was drawn from data given in a paper by Allred[8]. It shows two seemingly contradictory results. On one end of the scale, coke gets finer in size after calcining, whereas on the other end of the scale coke is coarser after calcining. What appears to be happening is that the coarse coke is getting degraded during calcining, and the original fine coke is either burning or carrying out of the calciner as dust. For example, before calcining, 50% of the green coke was +0.4", and 11% was -48 mesh. After calcining, there was practically no +0.4' or -48 mesh coke. The problem that may arise is apparent from Figure 6, which shows a size analysis of green Santa Maria Fine coke. This coke is considerably finer than most green cokes that are calcined. (Feed is commonly up to 3 or 4 inches in a normal calciner. It is difficult to predict how the finer material will act in standard calcining equipment, but Figure 5 suggests that it may burn or blow out with the off-gases. On the positive side, the temperatures are lower and conditions less severe with steam calcining, so that may alleviate much of the potential problem. Also, with a smaller, more uniform size feed, bed conditions will be altogether different, so it is impossible to say how the calciner will operate.

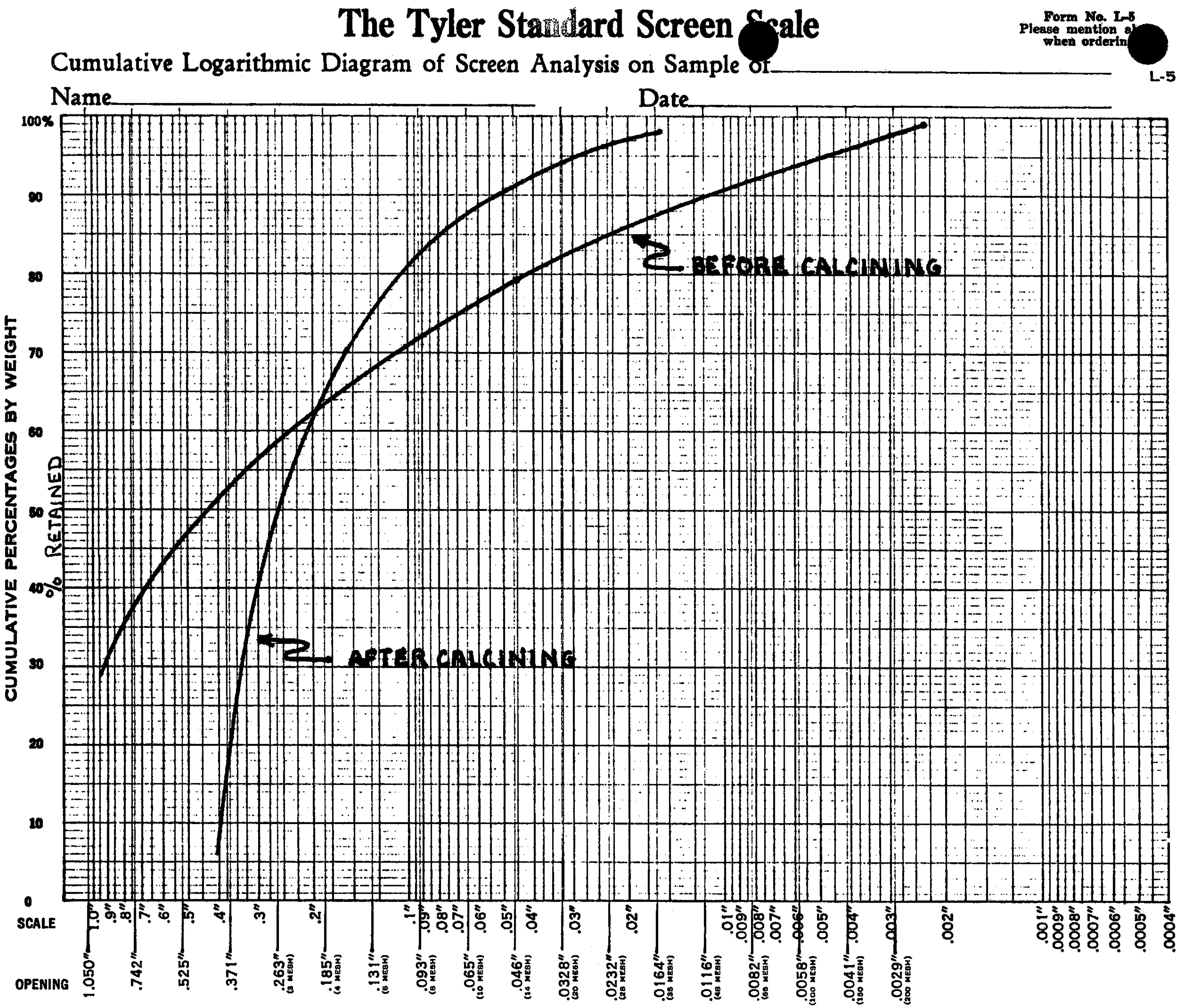

FIGURE 5 – TYPICAL SCREEN ANALYSIS OF PETROLEUM COKE CALCINING FEED AND PRODUCT

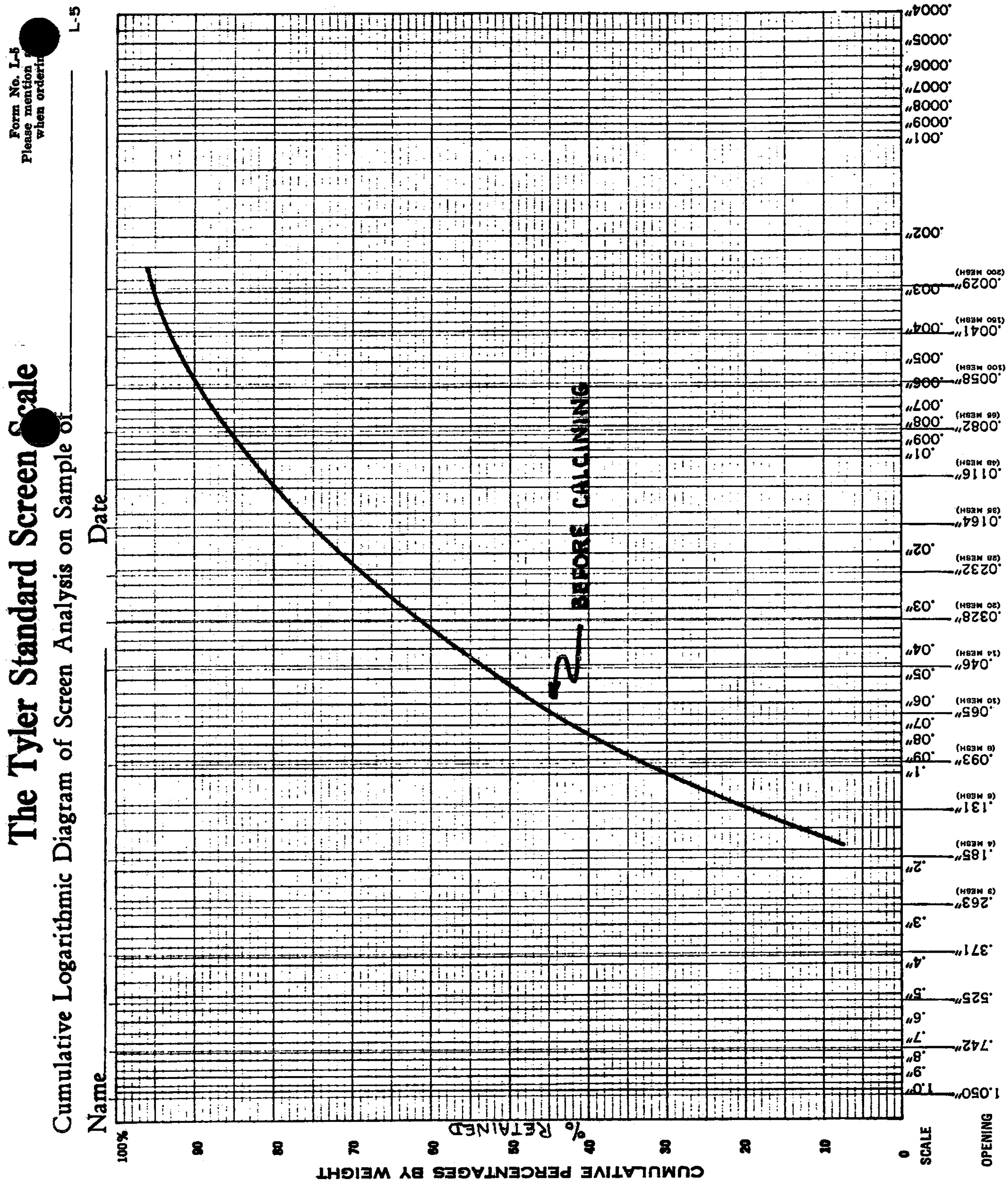

FIGURE 6 – SCREEN ANALYSIS OF SANTA MARIA FINES COKE BEFORE CALCINING

RECOMMENDATIONS

Since the coke requirement is so critical to the overall process, it is recommended that the aid of equipment vendors, calciner operators, and/or activated carbon producers be solicited as soon as possible. The questions that must still be answered can be answered most quickly and accurately by those who have a great deal of experience in coke calcining and activated carbon production.

Internally, the area of most uncertainty that can be addressed is the question of coke sizing requirements. What size is actually required for the chlorination reaction? Can coarse green coke be calcined with steam and then crushed and sized? Can fine (undersized) coke be somehow agglomerated and used in the chlorinator?

REFERENCES

1. Kennedy Van Saun Corporation, "Coke Calcining Systems," Bulletin COK 1/81(2), Figure F-6, p. 5.

2. Kennedy Van Saun Corporation, pp. 2-3.

3. Thomas Reis, "To Coke, Desulfurize and Calcine," Coking Handbook, (Gulf Publishing Company, 1982), p. 18.

4. Reis, p. 17.

5. V. Dean Allred, "Rotary Hearth Calcining of Petroleum Coke," Prepring #A71-26, The Metallurgical Society of AIME.

6. K. Weisbrod: Private communication between Weisbrod and B. R. Joyce, Wites Carbon 10/31/83.

7. Reis, p. 17.

8. Allred, p. 321.

APPENDIX I

CAPITAL COST DATA WORKSHEETS

The basic capital cost information used is shown in Tables Al and A2. The plant was built to calcine 1480 tons of green coke per day (maximum capitacity = 1644 tons per day) using two-61 ft diameter rotary hearth calciners. The block flow diagram and plot plan for the Cherry Point calciner installation are shown as Figures Al and A2.

In order to use the Cherry Point cost information to estimate the steam calciner costs, the original information was first re-arranged to show costs in a more compact format. Then the costs were adjusted, area-by-area, based on size of equipment, capacity, storage requirements, etc. The installed costs total was then used as a base for adding engineering, indirects, etc. in the same proportions as the actual costs from Cherry Point.

Since the Cherry Point costs were actual costs, no contingency was shown in the summary. Because the steam calciner is an estimate, a contingency must be added. The selection of 25% was somewhat arbitrary. It could be argued that a larger number should be used, since this is only a conceptual estimate without any flowsheet, equipment specification, engineering, etc. The figure of 25% was considered adequate, since the costs are factored from as-built costs less than five years old.

Costs were updated from 1978-79 using an M&S factor of 770/572.

Bechtel Job No. 12339
ARCO Cherrypoint, Washington
Coke Calcining Project

FINAL JOB COST SUMMARY
($ in U.S. 1,000's)

		P. O. Value	Spare Parts Over $500	Str.Stl. Incorp.	Concrete FDN/Slab	Direct Labor	S/C $	Distrib.	Fee & Bonus	H.O.	Total
C	Column & Vessels	$ 14	$ -	$ 1	$ 2	$ 10	$ -	$ 9	$ 1	$ 4	$ 41
D	Tanks	294	-	99	183	349	798	322	52	230	2,327
E	Exchangers	2,307	428	-	50	103	45	95	77	341	3,446
F	Rotary Hearth	5,470	12	(B)	123	1,333	1,004	1,230	232	1,035	10,439
	Waste Heat Boilers	3,016	-	(B)	21	429	-	396	98	435	4,395
G	Pumps & Drivers	105	-	-	4	26	-	24	4	18	181
K	Compressors & Blowers	(A)	-	-	-	(A)	-	-	-	-	-
T	Special Equipment*	2,554	-	253	19	476	4	440	95	422	4,263
J	Computers	133	-	-	-	5	-	5	4	16	163
	Field Installed Instrumentation	403	-	-	-	129	7	119	17	74	749
L	Above Ground Piping	664	-	118	18	641	-	592	51	229	2,313
	Below Ground Piping	31	-	-	-	-	106	-	3	15	155
M	Structural Steel	-	-	-	-	-	89	-	2	10	101
N	Field Installed Insulation	-	-	-	-	-	483	-	12	54	549
P	Electrical	954	-	11	48	1,149	102	1,060	84	375	3,783
Q	Concrete	-	-	-	-	-	65	-	2	7	74
R	Permanent Buildings	1	-	1,351	449	918	685	847	108	479	4,838
S	Site Improvements	174	-	7	12	532	744	491	50	221	2,231
X	Painting	1	-	-	-	-	308	-	8	35	352
	TOTAL	$16,121	$ 440	$1,840	$ 929	$6,100	$4,449	$5,630	$ 900	$4,000	$40,400

* "T" account is further broken down in page 2.
(A) Material & labor costs included with Waste Heat Boilers.
(B) Structural Steel material costs are part of the P.O. value.

TABLE A-1: TOTAL COST SUMMARY - 1480 SHORT TONS PER DAY GREEN COKE

Bechtel Job No. 12339
ARCO Cherrypoint, Washington
Coke Calciner Project

FINAL JOB COST SUMMARY
($ in U.S. 1,000's)

I SPECIAL EQUIPMENT*	P. O. Value	Spare Parts Over $500	Str. Stl. Incorp.	Concrete FDN/Slab	Direct Labor	S/C $	Distrib.	Fee & Bonus	H. O.	Total
Belt Conveyors	$ 947	$ -	$140	$ 11	$193	$ 4	$ 178	$ 37	$166	$1,676
Portal Reclaimer	625	-	-	-	94	-	87	20	91	917
Dust Collection System	117	-	-	-	18	-	17	4	17	173
FGD Equipment	653	-	-	-	98	-	91	21	95	958
Soda Ash Unloading Sys.	65	-	-	-	10	-	9	2	9	95
Rail Car Loading Access.	35	-	113	8	46	-	43	6	28	279
Desuperheater	27	-	-	-	4	-	4	1	4	40
Scales - Rail & Belt Type	44	-	-	-	7	-	6	2	6	65
Others	41	-	-	-	6	-	5	2	6	60
TOTAL	$2,534	$-0-	$253	$ 19	$476	$ 4	$ 440	$ 95	$422	$4,263

* This is a detailed breakdown of the "T" account, the total costs is included in page 1 summary.

- 2 -

TABLE 2A – SPECIAL EQUIPMENT COST SUMMARY – 1480 TONS PER DAY GREEN COKE

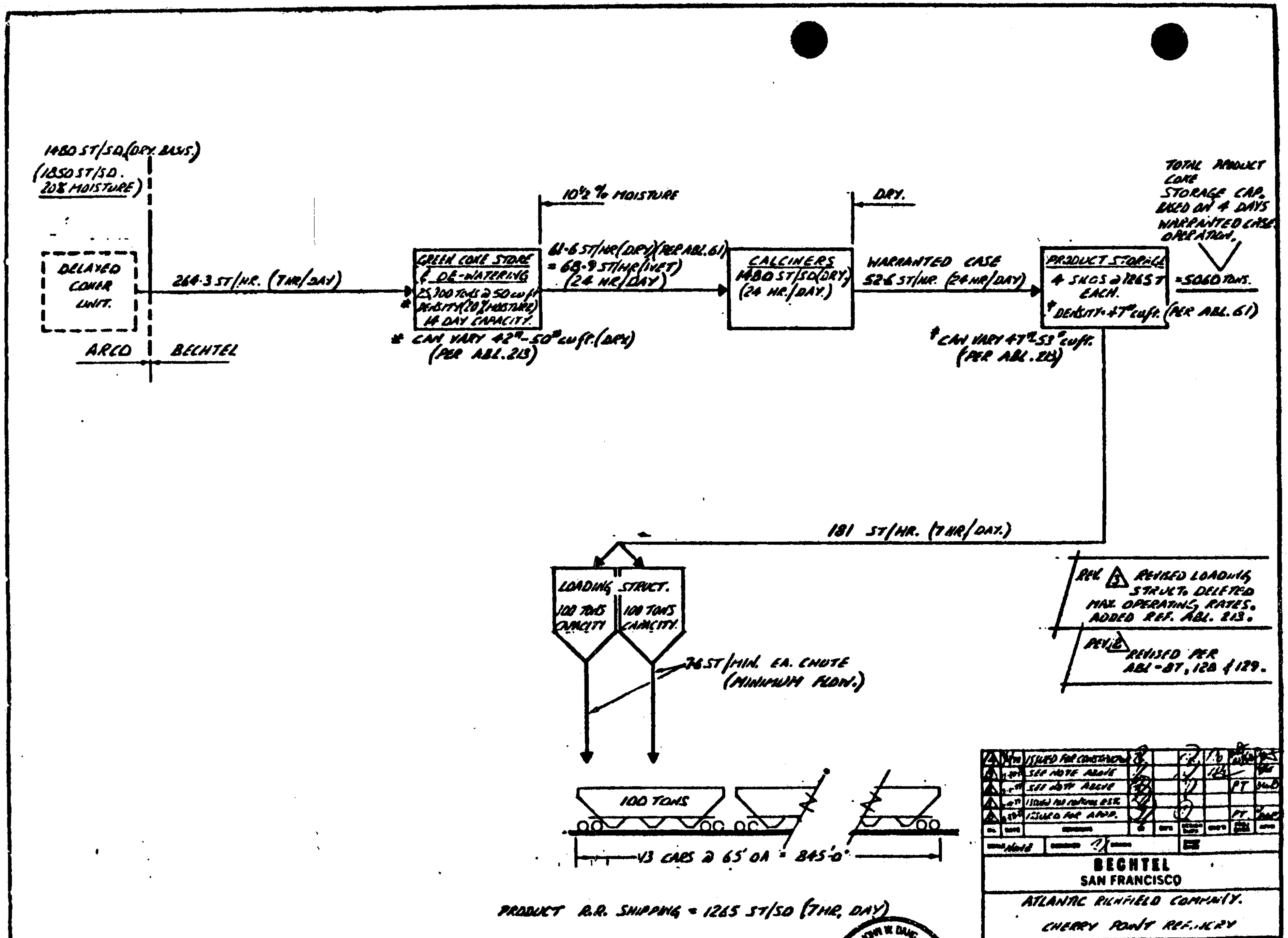

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FIGURE A1 – CHERRY POINT CALCINER BLOCK FLOW DIAGRAM

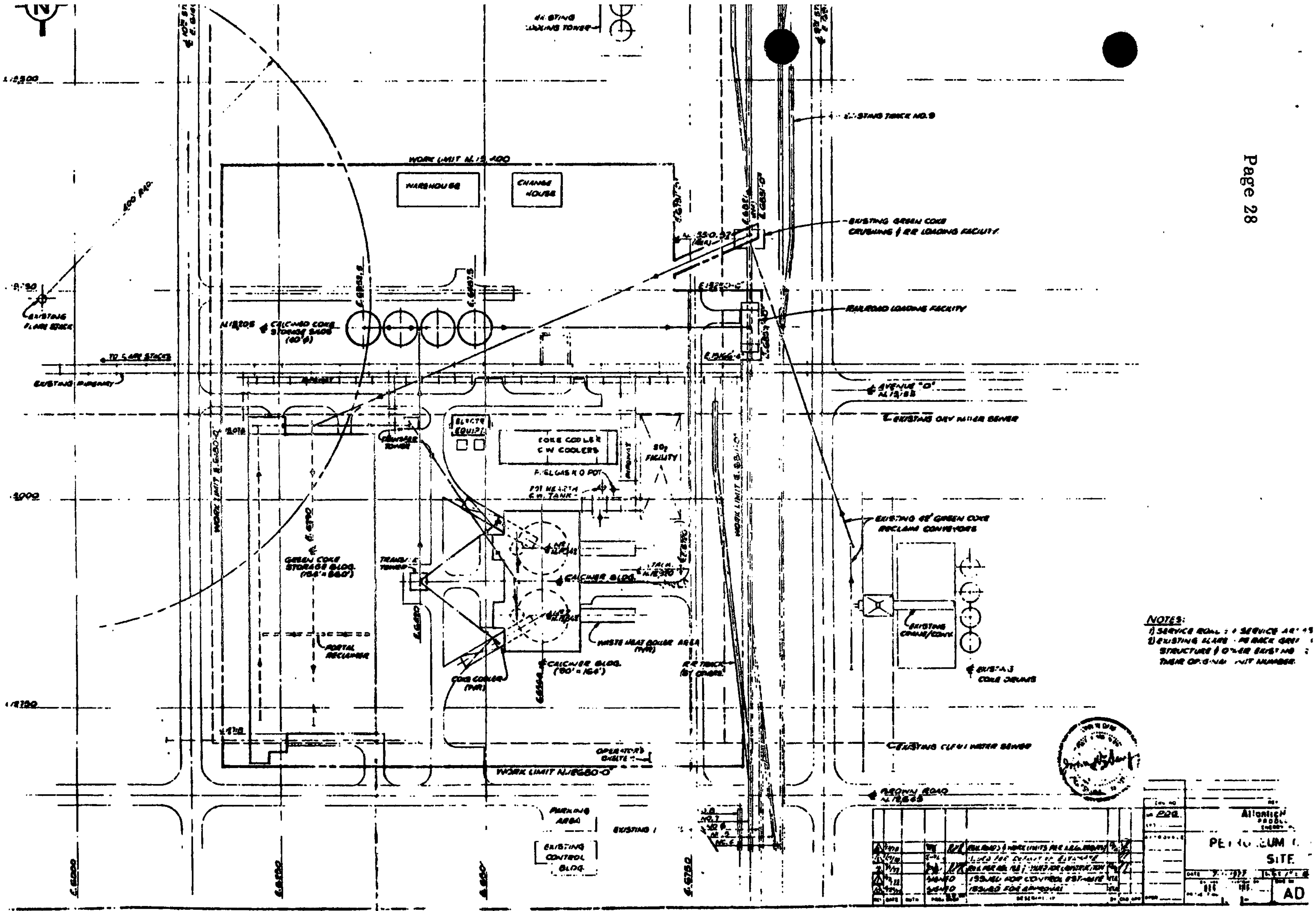

FIGURE 2A - CHERRY POINT CALCINER PLOT PLAN

General Purpose Worksheet

Subject	COKE CALCINING - CHERRY POINT ACTUAL TOTAL	Page No. 1	Of
File		By DM	Date

CHERRY POINT COSTS:

	P.O. VALUE	TOTAL
COLUMNS & VESSELS	$ 14	$ 41
TANKS	294	2,3 27
EXCHANGERS	2,307	3,446
ROTARY HEARTH	5,470	10,439
W.H. BOILERS	3,016	4,395
PUMPS / DRIVERS	105	181
SPECIAL EQUIP	2,554	4,263
BLDGS		4,838
SITE DEVELOP		2,231
INSTRUMENTATION		912
PIPING		2,468
STRUCT STEEL		101
INSULATION		549
ELECTRICAL		3,783
CONCRETE		74
PAINT		352
TOTAL	$ 13,760	$ 40,400

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General Purpose Worksheet

Subject: CORE CALCINING - CHERRY POINT ACTUAL TOTAL	Page No. 2	Of
File	By	Date

CHERRY POINT COSTS: (Re-organized)

	PURCHASED EQUIPMENT	TOTAL INSTALLED ①
COLUMNS & VESSELS	$ 14	$ 33
TANKS	294	1840
EXCHANGERS	2,307	3,421
ROTARY HEARTH	5,470	10,102
WASTE HEAT BOILERS	3,016	4,664
PUMPS / DRIVERS	105	177
SPECIAL EQUIP.	2 554	4,320
BLDGS		3,404
SITE DEVELOP		1,469
	TOTAL DIRECTS	$ 29,430
FIELD INDIRECTS ②		5,630
	TOTAL FIELD COST	$ 35,060
ENGINEERING & H.O. ③		4,000
FEE		900
	SUB-TOTAL CAPITAL	$ 39,960
SPARES (over $500)		440
	TOTAL CAPITAL COST	$ 40,400 ④

① TOTAL INSTALLED = P.O. VALUE + STR. STEEL + CONCRETE + DIR LABOR + s/c + (Pro-rated portion of instrumentation, piping, elec., etc. based on P.O. value). Pro-ration not added to bldgs & site)

② FIELD INDIRECTS = "Distrib" TOTAL

③ ENGINEERING & H.O. = "H.O. TOTAL"

④ TCC excludes working capital, start-up capital, OBL, owners cost, taxes.

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General Purpose Worksheet

Subject: CORE CALCINING - CHERRY POINT ACTUAL TOTAL | Page No. 3 | Of

File: 1978-79 # | By | Date

CHERRY POINT COSTS: (Re-organized)

	PURCHASED EQUIPMENT	TOTAL INSTALLED (1)	[illegible]
COLUMNS + VESSELS	$ 14	$ 33	$ 15
TANKS	294	1840	1564
EXCHANGERS	2,307	3,421	1026
ROTARY HEARTH	5,470	10,102	4203
WASTE HEAT BOILERS	3,016	4,664	1399
PUMPS/DRIVERS	105	177	81
SPECIAL EQUIP.	2 554	4,320	2766
BLDGS		3,404	3000
SITE DEVELOP.		1,469	1000
	TOTAL DIRECTS	$ 29,430	15,059
FIELD INDIRECTS (2)		5,630	2,881
	TOTAL FIELD COST	$ 35,060	$ 17,940
ENGINEERING & H.O. (3)		4,000	2,047
FEE		900	461
	SUB-TOTAL CAPITAL	$ 39,960	$ 20,448
SPARES (over $200)		440	133
	TOTAL CAPITAL COST	$ 40,400 (4)	$ 20,581
CONTINGENCY - 25%			5,145
			25,726

1984 $ = $ 24,631

(1) TOTAL INSTALLED = P.O. VALUE + STR. STEEL + CONCRETE + DIR LABOR + s/c + (Pro-rated portion of instrumentation, piping, elec., etc. based on P.O. value). Pro-ration not added to bldgs & site)

(2) FIELD INDIRECTS = "Distrib" TOTAL

(3) ENGINEERING & H.O. = "H.O. TOTAL"

(4) TCC excludes working capital, start-up capital, OBL, owner's cost, taxes.

AR3B-1473-D

General Purpose Worksheet

Subject: COKE CALCINING	Page No. 4 Of
File	By / Date

Adjust Cherry Point from 61.6 TPH calciner feed to 16.9 TPH, assuming same equipment, but allowing for different storage capacity, etc.

COLUMNS & VESSELS

In-process bins, storage vessels, etc. Assume cost proportional to capacity.

$$(\$44)\left(\frac{16.9}{61.6}\right)^{.6} = \underline{\underline{\$6.4 \text{ (P.E.)}}} \times \frac{33}{15} = \underline{\underline{\$15 \text{ (INST.)}}}$$

TANKS

Silos, bins, hoppers, chutes. Includes 4 - 40'ϕ storage silos and product loading chutes. Also in-process bins, hoppers, etc.

Need 21 days product storage = 228 TPD × 21 = 4788 TONS

4788 TONS @ $40^{\#}/ft^3$ = 239,400 ft^3 req'd

Cherry Point silos = storage for 5060 tons ≃ same.

Need silos, but not loading chutes. Other bins, hoppers, etc. could be down sized. Assume 80% of cost of tanks is silos, and add 5% for other.

$$\$294 \times .85 = \underline{\underline{\$249.9 \text{ (P.E.)}}} \times \frac{1840}{294} = \underline{\underline{\$1564 \text{ (INST.)}}}$$

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General Purpose Worksheet

Subject CORE CALCINING	Page No. 5	Of
File	By	Date

EXCHANGERS

CHERRY POINT @ 1290°C vs STEAM CALCINING @ 950°C } Cherry Point larger and hotter.

Should base comparison on h.e. surface area, which is based on BTU/hr, but don't have enough information to do with any accuracy.

For approximation, see worksheet. W-5)

$A_{STEAM\ CALC} / A_{CHERRY\ POINT} \approx 0.3$

$2,307 × 0.3 = $692 (P.E.) × $\frac{3421}{2307}$ = $1,026 (INST)

ROTARY HEARTH

CHERRY POINT HAS 2 UNITS @ 740 TPD each (30.8 TPH)

- ~40 MIN RESIDENCE TIME
- 61' Φ hearth
- ~15 MIN IN SOAKING PIT
- 4-5" ACTIVE BED

STEAM CALCINING – 16.9 TPH

- ~30 MIN RESIDENCE (finer particle size will require milder calcining & rabbling to avoid fines loss, but will also react faster. Also, lower temp will result in less "violent" calcining.

Need 45' Φ hearth. (see worksheet) (W-6)

2 - 61' Φ = $5,470. Assume 1 = $2,735.

For 45' : $2,735 $\left(\frac{45}{61}\right)^{.6}$ = $2,279 (P.E.) × $\left(\frac{10,102}{5,470}\right)$ = $4,208 (INST)

General Purpose Worksheet

Subject: CORE CALCINING	Page No. 6	Of
File	By	Date

WASTE HEAT BOILERS

Use same factor as Heat Exchangers (0.3)

$\$3,016 \times .3 = \$905$ (P.E.) $\times \frac{4664}{3016} = \$1399$ INST.

PUMPS / DRIVERS

Mainly should be for cooling water, FGD liquor, spills runoff, etc.

Assume = f (feed rate)

$\$105 \left(\frac{169}{616}\right)^{.6} = \$48$ (P.E.) $\times \frac{177}{105} = \$81$ (INST)

SPECIAL EQUIPMENT

Belt Conveyors = Cherry Point has apparently ~2000' of conveyors, probably much of it due to building at existing plant. Cost (p.e) ~ 947,000/2000 = $475/ft. New plant could concievably get by with less conveying (new layout, no loading, single MHC) Assume ~1100 ft needed. Also assume belt is ~1/2 width, @ ~$250/ft.

Belts = 1100' × 250/ft = $275 (P.E.)

Portal Reclaimer = same as C.P. = $625 (P.E.)

Dust Collection = feed rate only 30%, but much finer feed, so assume same dust collection = $117 (P.E.)
Effectively = 3.? X Dust [illegible]

General Purpose Worksheet

Subject	Page No. 7	Of
File	By	Date

SPECIAL EQUIPMENT (cont'd)

FGD Equipment = Assume S° same in Cherry Point coke as in Santa Maria.
Assume FGD = f(feed rate) $\$653 \left(\frac{16.9}{61.6}\right)^{.6} =$ **\$301 P.E.**

Soda Ash Unloading = same as Cherry Point = **\$65 (P.E.)**

Rail Car Loading = delete **\$0**

De Superheater = same as W.H.B. = 0.3 × 27 = **\$8. (P.E.)**

Scales (Rail & Belt) - delete rail (part of Al smelter)
assume belt @ = **\$10 (P.E.)**

Others = $\$41 \left(\frac{16.9}{61.6}\right)^{.6} =$ \$19 (P.E.)

Summary - Special Equip:

Belt Conveyors	\$275
Portal Reclaimer	625
WHB Boil	117
FGD	301
Soda Ash	65
Rail Loading	0
De Super-heater	8
Scales	10
Others	19
TOTAL	1,420 × 4320/2554 = **\$2,402 (INST)**

Add: Green Coke Unloading Facility = \$54 (P.E.)
2 - Hammer Mills @ \$32 = 64 (P.E.)
4 - Screens @ 16.6 = 67 (P.E.)
215 × 4320/2554 = **364**

\$ 2,766 ⇐

General Purpose Worksheet

Subject	Page No. 8	Of
File	By	Date

BUILDINGS :

CHERRY POINT :

Coke Storage = 154' × 360' = 55,440 ft² (~80%)

Calciner = 90' × 164' 14,760 ft² (~20%)

Other ? 70,200 ft²

$3,404 / 70.2 = 48.50 / ft²

Storage Bldg for steam calcining same

Assume Total bldgs = $3,000

SITE DEVELOPMENT :

CHERRY POINT = $1,469

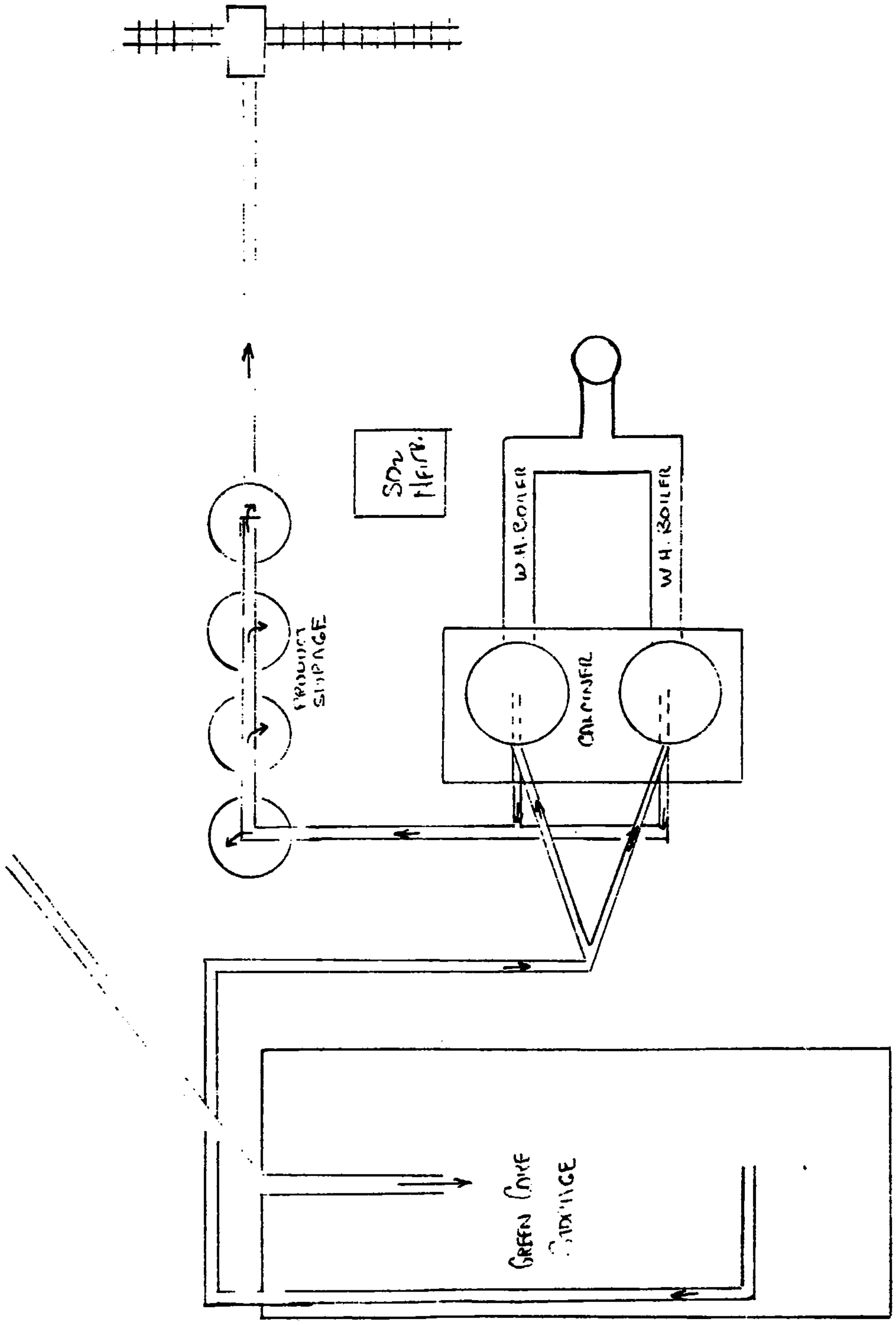
Should be less, because of synergistic effect and good planning with Al smelter

Assume $1,000

ARCO Coal Company
Division of AtlanticRichfieldCompany

Calculation/Graph Chart

Subject	Page No. VI-4	of
File	By	Date



General Purpose Worksheet

Subject CALCINING (HEAT EXCHANGERS)	Page No. W-5	Of
File	By	Date

HEAT EXCHANGERS :

CHERRY POINT (TOTAL) - $Q_{CP} = A_{CP} \times U_{CP} \times (t_2 - t_1)_{CP}$

STEAM CALCINING (TOTAL) $Q_{SC} = A_{SC} \times U_{SC} \times (t_2 - t_1)_{SC}$

where Q = BTU/hr heat transferred
A = transfer area
U = transfer co-efficient
t_2 = temperature of hot side
t_2 = temperature of cold side

Let : $U_{CP} = U_{SC}$
$t_{2_{CP}} = 2350°F$
$t_{2_{SC}} = 1740°F$
$t_{1_{CP}} = t_{2_{CP}} = 200°F$

$$Q_{CP} / Q_{SC} = \frac{U_{CP} \times A_{CP} \times (2350-200)}{U_{SC} \times A_{SC} \times (1740-200)}$$

$Q_{CP}/Q_{SC} \approx 1.4 \; A_{CP}/A_{SC}$

$A_{SC} = (1.4 \, A_{CP})(Q_{SC}) / Q_{CP}$

$Q_{CP}/Q_{SC} = (61.6/16.9) = 3.6$ due to feed rate

$= 2350/1740 = 1.3$ due to temp

= say 4.8 overall

$A_{SC} = 1.4 \, A_{CP} / 4.8 = A_{CP} \times .3$

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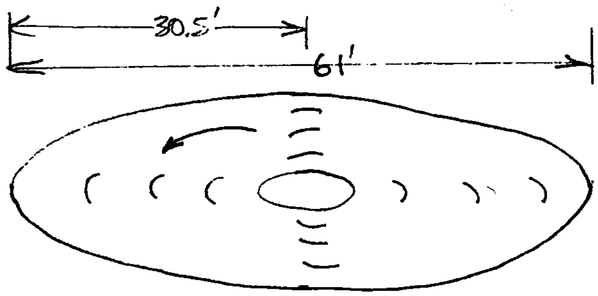
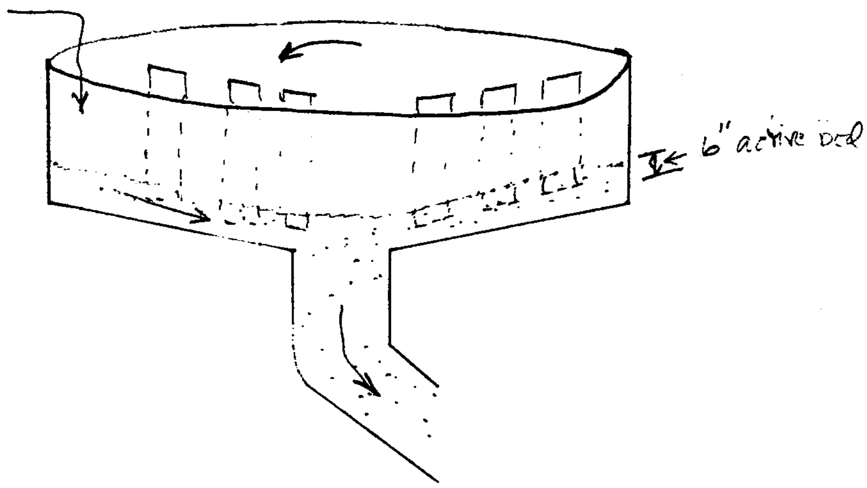
General Purpose Worksheet

Subject: Rotary Hearth	Page No: W-6	Of
File	By: DM	Date





Residence Time = f (Bed Depth, Feed Rate, Rotation Speed)

Based on volume : Volume of active bed = $\pi r^2 h = \pi (30.5)^2 (.5) = 1461\ ft^3$

$1461\ ft^3 \div 30.8\ TPH = 47.4\ ft^3/TPH$

for 16.9 TPH, $(47.4)(16.9) = 801\ ft^3$ req'd

$801 = (\pi)(R^2)(.5)$

$R = 22.6'$
$\Phi = 45'$

KW: [redacted]
Facilities general agreements
U.S. Bureau of Mines
14-09-0070-1109
Extension No. 1

277

EXTENSION OF MEMORANDUM OF AGREEMENT
BETWEEN
U.S. DEPARTMENT OF THE INTERIOR,
BUREAU OF MINES
AND
ARCO METALS CO., A DIVISION OF ATLANTIC RICHFIELD COMPANY

The memorandum of agreement between the United States of America, through the Department of the Interior, Bureau of Mines, and ARCO Metals Co., dated August 12, 1983, for the purpose of extending the gathering of information related to technology for recovering alumina from domestic nonbauxitic resources, specifically the clay-HCl leach, HCl gas sparging crystallization process, is hereby extended for the period August 12, 1984 to August 11, 1985.

U.S. DEPARTMENT OF THE INTERIOR

By ______________________
Assistant Director, Minerals
and Materials Research

Date: AUG 24 1984

Approved:

____
Acting Director

Date: 8-28-84

ARCO METALS, CO., A DIVISION
OF ATLANTIC RICHFIELD CO.

By ______________________

Date: August 13, 1984

Approved:

____
Vice President of Research

Date: August 16/84